CLASSICAL THEORY OF ORBITAL PRECESSION AND GRAVITATIONAL DEFLECTION

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ABSTRACT

Orbital precession and gravitational deflection are explained straightforwardly using classical lagrangian dynamics in the non relativistic limit. Therefore these phenomena cannot be used as a test of Einsteinian general relativity (EGR), now known clearly to be riddled with basic errors. Planetary precession can be interpreted as a Coriolis force using elementary methods in which total angular momentum is conserved. The force law for planetary precession and gravitational deflection is a sum of two terms, inverse square and inverse cubed in r. This result is derived in two independent ways and the effect of precession calculated on the Keplerian equation for orbital linear velocity. Gravitational deflection theory is developed using the same methods and it is shown that light can be trapped by a finite mass. It is well known that there are no black holes in nature.

Keywords: Classical theory of orbital precession and gravitational deflection, ECE theory.

UFT 215

1. INTRODUCTION

In the obsolete literature of the twentieth century it was claimed erroneously that there existed phenomena of astronomy that could be used to test Einsteinian general relativity (EGR). It is now accepted that EGR is riddled with errors (1 - 10}, and it has become well known that criticisms of EGR have existed for nearly a century, an era of pseudoscience in cosmology. This is an example of Langmuir's "pathological science" at its worst. The ECE theory on the other hand is rigorously correct and has been accepted as the new natural philosophy. Currently it exists alongside the old pseudoscience. If natural philosophy is to continue to be a rational subject, pseudoscience mut be recognized as such and replaced by a plausible theory based on correct mathematics. ECE is one such theory, it is a generally covariant unified field theory based on correct geometry. In its non relativistic limit it reduces to classical dynamics.

In Section 2, elementary Lagrangian dynamics {11} are used to give a straightforward explanation of planetary precession in terms of a Coriolis force, and considerations given to the orbital velocity and angular momentum of a precessing elliptical orbit. Elementary kinematics are used to derive the force law for a precessing elliptical orbit, the result being consistently the same as that from Lagrangian dynamics. In section 3 the lagrangian theory is developed in detail, and the Keplerian equation for orbital linear velocity derived. The effect of precession on this velocity is calculated classically, giving an equation that can be tested with data. Finally the same methods are used to calculate gravitational deflection classically, for example light deflection due to gravitation. In Section 4 some graphical results are given of the precessing conical section equation used in this simple lagrangian theory, and it is shown that light can be trapped by a finite mass M. It is well known that the "black hole" theory based on EGR is riddled with numerous errors {1 - 10}, and this new theory is a much simpler, much clearer, and above all scientific explanation of orbiting light being trapped by a finite mass.

2. FORCE, LINEAR VELOCITY AND ANGULAR MOMENTUM

Consider the elementary equation {11}:

$$\left(\frac{d\underline{Q}}{dt}\right)_{fixed} = \left(\frac{d\underline{Q}}{dt}\right)_{rotating} + \underline{\omega} \times \underline{Q} \quad -(1)$$

where $\underline{Q}$ is any vector and $\underline{\omega}$ is the angular velocity of a frame rotating in the laboratory frame. Let:

$$\underline{Q} = \underline{p} \quad -(2)$$

where

$$\underline{p} = m\underline{v} \quad -(3)$$

is the linear momentum of a mass m. Then the forces in the fixed and rotating frames are related by:

$$\underline{F}_{fixed} = \underline{F}_{rotating} + m\,\underline{\omega} \times \underline{v} \quad -(4)$$

where

$$\underline{F}_{Coriolis} = m\,\underline{\omega} \times \underline{v} \quad -(5)$$

is the Coriolis force. In the preceding paper UFT214 (www.aias.us) it was shown that

$$\underline{F}_{fixed} = -\frac{k_1}{r^2}\left(x^2 + (1-x^2)\frac{\alpha}{r}\right)\underline{e}_{rf}, \quad -(6)$$

$$\underline{F}_{rotating} = -\frac{k}{r^2}\underline{e}_{r\,rot} \quad -(7)$$

for a precessing elliptical orbit described experimentally by the conical section equation:

$$r = \frac{d}{1 + \epsilon \cos(x\theta)} \quad -(8)$$

Here $2d$ is the latus rectum (right latitude), ϵ is the eccentricity, x the precession constant and k a constant. The plane polar coordinates are (r , θ). In Eqs. (6) and (7) the unit vectors of the fixed and rotating frames are defined in UFT214:

$$\underline{e}_{rf} = \underline{i} \cos\theta + \underline{j} \sin\theta \quad -(9)$$

$$\underline{e}_{rot} = \underline{i} \cos(x\theta) + \underline{j} \sin(x\theta) \quad -(10)$$

The constant k_1 is defined by:

$$k_1 = x^2 k = x^2 m M G \quad -(11)$$

where the mass m orbits a mass M. The Newton constant is G and the half right latitude is defined by:

$$d = \frac{L^2 - m k d (1 - x^2)}{m k_1} . \quad -(12)$$

Therefore orbital precession can be explained on the classical level by the Coriolis force:

$$\underline{F}_{Coriolis} = -\frac{k}{r^2} \Big[\underline{i} \left(\left(x^2 + (1 - x^2) \frac{d}{r} \right) \cos\theta - \cos(x\theta) \right) + \underline{j} \left(\left(x^2 + (1 - x^2) \frac{d}{r} \right) \sin\theta - \sin(x\theta) \right) \Big] ;$$

$$\text{for } k_1 \sim k \quad -(13)$$

which vanishes when

$$x = 1 \quad -(14)$$

in which case there is no precession. This phenomenon cannot be used as a test of EGR, which is riddled with errors as is well known {1 - 10}.

When:

$$\underline{Q} = \underline{r} \quad -(15)$$

in eq. (1) then:

$$\left(\frac{d\underline{r}}{dt}\right)_{fixed} = \left(\frac{d\underline{r}}{dt}\right)_{rotating} + \underline{\omega} \times \underline{r} \quad -(16)$$

where:

$$\underline{v}_{fixed} = \left(\frac{d\underline{r}}{dt}\right)_{fixed} = \dot{r}\,\underline{e}_{rf} + r\dot{\theta}\,\underline{e}_{\theta} \quad -(17)$$

$$\underline{v}_{rotating} = \left(\frac{d\underline{r}}{dt}\right)_{rotating} = \dot{r}\,\underline{e}_{rr} + r\dot{\beta}\,\underline{e}_{\beta} \quad -(18)$$

are the orbital linear velocities in the fixed and rotating frames. The unit vectors are defined by:

$$\underline{e}_{rf} = \underline{i}\cos\theta + \underline{j}\sin\theta \quad -(19)$$

$$\underline{e}_{rr} = \underline{i}\cos\beta + \underline{j}\sin\beta \quad -(20)$$

$$\underline{e}_{\theta} = -\underline{i}\sin\theta + \underline{j}\cos\theta \quad -(21)$$

$$\underline{e}_{\beta} = -\underline{i}\sin\beta + \underline{j}\cos\beta, \quad -(22)$$

$$\beta = x\theta, \quad -(23)$$

so the difference in velocity between fixed and rotating frames is:

$$\begin{aligned}\underline{\omega} \times \underline{r} &= \underline{v}_{fixed} - \underline{v}_{rotating} \quad -(24)\\ &= \underline{i}\left[\dot{r}\left(\cos\theta - \cos(x\theta)\right) - r\dot{\theta}\left(\sin\theta - x\sin(x\theta)\right)\right]\\ &\quad + \underline{j}\left[\dot{r}\left(\sin\theta - \sin(x\theta)\right) + r\dot{\theta}\left(\cos\theta - x\cos(x\theta)\right)\right]\end{aligned}$$

and this difference vanishes when there is no precession, i.e when:

$$x = 1. \quad -(25)$$

This is again a classical explanation of precession.

The total angular momentum is a constant of motion in this lagrangian analysis {11}. In the fixed frame the total angular momentum is:

$$\underline{L} = \underline{r} \times \underline{p} \quad -(26)$$

where {11}:

$$\underline{r} = r\,\underline{e}_r \quad -(27)$$

$$\underline{p} = m\underline{v} = m\left(\dot{r}\,\underline{e}_r + r\dot{\theta}\,\underline{e}_\theta\right). \quad -(28)$$

So:

$$\underline{L} = mr^2\dot{\theta}\,\underline{e}_r \times \underline{e}_\theta = mr^2\dot{\theta}\,\underline{k} \quad -(29)$$

which is the same result as the lagrangian method {11}, but derived using the elementary kinematics of planar rotation. In the moving frame the total angular momentum is:

$$\underline{L}_m = \underline{r} \times \underline{p}_m \quad -(30)$$

where the linear momentum in the moving frame is:

$$\underline{p}_m = m\underline{v}_m = m\left(\dot{r}\,\underline{e}_{rm} + r\dot{\beta}\,\underline{e}_\beta\right). \quad -(31)$$

Here:

$$\underline{r} = r\,\underline{e}_{rm}. \quad -(32)$$

Therefore:

$$\underline{L}_m = mr^2\dot{\beta}\,\underline{e}_{rm} \times \underline{e}_\beta = xmr^2\dot{\theta}\,\underline{k} \quad -(33)$$

and again this is the same result as the lagrangian method. Both $\underline{L}$ and $\underline{L}_m$ are constants of motion so

$$\underline{L} - \underline{L}_m = (1-x) m r^2 \omega \underline{k} = \text{constant}. \quad -(34)$$

The torques associated with $\underline{L}$ and $\underline{L}_m$ can be defined as:

$$\underline{T} = \frac{1}{2} \omega \underline{L}, \quad \underline{T}_m = \frac{1}{2} \omega \underline{L}_m \quad -(35)$$

and so there is an extra torque due to precession. In ECE theory this torque is due to spacetime torsion. It is plausible to assume that the extra precessional torque is caused by the well known rotation of the sun.

Elementary kinematics of plane polar coordinates produce the acceleration:

$$\underline{a} = (\ddot{r} - r\dot{\theta}^2)\underline{e}_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta})\underline{e}_\theta. \quad -(36)$$

This is a general result as is well known. For a precessing elliptical orbit of type (8):

$$\frac{dr}{d\theta} = \frac{x\epsilon}{\alpha} r^2 \sin(x\theta) \quad -(37)$$

the conserved angular momentum from lagrangian dynamics {11} is:

$$L = mr^2\dot{\theta} = mr^2 \frac{d\theta}{dt}. \quad -(38)$$

Therefore:

$$\dot{r} = \frac{dr}{dt} = \frac{dr}{d\theta}\frac{d\theta}{dt} = \frac{xL\epsilon}{m\alpha} \sin(x\theta) \quad -(39)$$

and

$$\dot{\theta} = \frac{L}{mr^2}. \quad -(40)$$

The second derivatives are

$$\ddot{r} = \frac{x^2 L^2 \epsilon}{m^2 \alpha r^2} \cos(x\theta) \quad -(41)$$

and

$$\ddot{\theta} = -\frac{2L^2 x \epsilon}{m^2 r^3 \alpha} \sin(x\theta). \quad -(42)$$

The angular dependent part of the acceleration vanishes:

$$r\ddot{\theta} + 2\dot{r}\dot{\theta} = 0 \quad -(43)$$

and the radial part is given by:

$$\ddot{r} - r\dot{\theta}^2 = \frac{x^2 L^2 \epsilon}{m^2 \alpha r^2} \cos(x\theta) - \frac{L^2}{m^2 r^3}. \quad -(44)$$

From Eq. (8):

$$\cos(x\theta) = \frac{1}{\epsilon}\left(\frac{\alpha}{r} - 1\right) \quad -(45)$$

and the acceleration is:

$$\underline{a} = \left(\frac{L}{m}\right)^2 \left(\frac{(x^2-1)}{r^3} - \frac{x^2}{\alpha r^2}\right) \underline{e}_r \quad -(46)$$

Finally the force law is:

$$\underline{F} = m\underline{a}. \quad -(47)$$

If there is no precession then:

$$x = 1 \quad -(48)$$

and the force law reduces to:

$$\underline{F} = -\frac{L^2}{m\alpha r^2}\,\underline{e}_r. \quad -(49)$$

This is the Newtonian force law:

$$\underline{F} = -\frac{mMG}{r^2}\,\underline{e}_r \quad -(50)$$

if:

$$\alpha = \frac{L^2}{m^2 MG}. \quad -(51)$$

The same force law is obtained very elegantly from the following equation of lagrangian dynamics {11} for planar orbits of any type:

$$\frac{d^2}{d\theta^2}\left(\frac{1}{r}\right) + \frac{1}{r} = -\frac{mr^2}{L}F(r). \quad -(52)$$

In Eq. (52):

$$\frac{d^2}{d\theta^2}\left(\frac{1}{r}\right) = -\frac{x^2\epsilon}{\alpha}\cos(x\theta) \quad -(53)$$

so:

$$F(r) = \frac{L^2}{m}\left(\frac{(x^2-1)}{r^3} - \frac{x^2}{\alpha r^2}\right) \quad -(54)$$

and Eq. (47) is given directly, QED. The same force law is also true for any type of gravitational deflection, and so EGR is not needed. It is incorrect and obsolete.

3. SOME DETAILS OF THE LAGRANGIAN THEORY, KEPLERIAN VELOCITY AND DEFLECTION THEORY

For a planar orbit the coordinate system is the cylindrical polar system in a plane (r , θ). The Lagrangian is {11}:

$$\mathcal{L} = T - U \quad -(55)$$

where T is the kinetic energy and U the potential energy. From Section 2 the kinetic energy is:

$$T = \frac{1}{2} m v^2 = \frac{1}{2} m \left(\dot{r}^2 + \dot{\theta}^2 r^2 \right). \quad -(56)$$

Assume that the potential energy depends only on r:

$$U = U(r). \quad -(57)$$

The two Euler Lagrange equations are:

$$\frac{\partial \mathcal{L}}{\partial r} = \frac{d}{dt} \frac{\partial \mathcal{L}}{\partial \dot{r}} \quad -(58)$$

and

$$\frac{\partial \mathcal{L}}{\partial \theta} = \frac{d}{dt} \frac{\partial \mathcal{L}}{\partial \dot{\theta}} \quad -(59)$$

The total angular momentum is conserved, and is a constant of motion defined by:

$$L = \frac{\partial \mathcal{L}}{\partial \dot{\theta}}. \quad -(60)$$

So:

$$\frac{dL}{dt} = 0. \quad -(61)$$

In consequence:

$$L = mr^2\dot{\theta} \quad -(62)$$

and the angular velocity is:

$$\omega = \dot{\theta} = \frac{d\theta}{dt}. \quad -(63)$$

The Hamiltonian is the total energy E, which is also a constant of motion, and which is also conserved:

$$H = E = T + U. \quad -(64)$$

From Eqs. (58) and (59) it may be shown {11} that:

$$\frac{d^2}{d\theta^2}\left(\frac{1}{r}\right) + \frac{1}{r} = -\frac{mr^2}{L}F(r) \quad -(65)$$

where the force is defined by:

$$F(r) = -\frac{\partial U}{\partial r}. \quad -(66)$$

Note that Eq. (65) is true for any planar orbit. So Lagrangian dynamics are more general than Newtonian dynamics, which is true only for an elliptical orbit.

As shown in Section 2 the force law for a precessing elliptical orbit is given by Lagrangian dynamics as:

$$F(r) = \frac{L^2}{m}\left(\frac{(x^2-1)}{r^3} - \frac{x^2}{dr^2}\right). \quad -(67)$$

It is convenient to express this in terms of a constant k to be determined:

$$F(r) = -\frac{k}{r^2}\left(x^2 + (1-x^2)\frac{d}{r}\right). \quad -(68)$$

So the potential energy for the precessing elliptical orbit is:

$$U(r) = -\frac{k x^2}{r} - \frac{k(1-x^2)\alpha}{2r^2}. \quad -(69)$$

Therefore the Lagrangian for a precessing elliptical orbit is:

$$\mathcal{L} = \frac{1}{2}m(\dot{r}^2 + \dot{\theta}^2 r^2) + x^2\frac{k}{r} + \frac{(1-x^2)\alpha k}{2r^2}$$

$$= \frac{1}{2}m\dot{r}^2 + \frac{L^2}{2mr^2} + \frac{x^2 k}{r} + \frac{(1-x^2)\alpha k}{2r^2}. \quad -(70)$$

This expression can be rewritten as:

$$\mathcal{L} = \frac{1}{2}m\dot{r}^2 + \frac{L_1^2}{2mr^2} + \frac{k_1}{r} \quad -(71)$$

where:

$$k_1 = x^2 k = x^2 m M G \quad -(72)$$

and:

$$L_1^2 = L^2 - mk\alpha(1-x^2). \quad -(73)$$

Now define the Lagrangian function:

$$\mathcal{L} = \frac{1}{2}m(\dot{r}^2 + \dot{\beta}^2 r^2) - U(r) \quad -(74)$$

and the Euler Lagrange equation

$$\frac{\partial \mathcal{L}}{\partial \beta} = \frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{\beta}} \quad -(75)$$

The constant total angular momentum is:

$$L_1 = mr^2 \frac{d\beta}{dt} \quad -(76)$$

and the potential energy is:

$$U(r) = -\frac{k_1}{r}. \quad -(77)$$

The Hamiltonian is:

$$H = E = \frac{1}{2}m\left(\dot{r}^2 + \dot{\beta}^2 r^2\right) + U(r) \quad -(78)$$

so:

$$\dot{r} = \frac{dr}{dt} = \left(\frac{2}{m}\left(E + \frac{k_1}{r} - \frac{L_1^2}{mr^2}\right)\right)^{1/2}. \quad -(79)$$

Now use:

$$\frac{d\beta}{dr} = \frac{dt}{dr}\frac{d\beta}{dt} = \frac{L_1}{mr^2}\frac{dt}{dr}, \quad -(80)$$

from which the angle β is defined as

$$\beta(t) = \int \frac{L_1}{r^2}\left(2m\left(E + \frac{k_1}{r} - \frac{L_1^2}{2mr^2}\right)^{-1/2}\right) dr. \quad -(81)$$

Integrating gives:

$$\cos\beta = \frac{\left(\frac{L_1^2}{mk_1}\right)\frac{1}{r} - 1}{\left(1 + \frac{2EL_1^2}{mk_1^2}\right)^{1/2}}. \quad -(82)$$

This is eq. (8) provided that:

$$\alpha = \frac{L_1^2}{m k_1} \quad -(83)$$

and

$$\epsilon = \left(1 + \frac{2EL_1^2}{m k_1^2}\right)^{1/2} \quad -(84)$$

Therefore classical Lagrangian dynamics gives a precessing orbit, QED. The Newtonian orbit is given by:

$$x = 1. \quad -(85)$$

This theory can be used to find the effect of precession on the linear orbital velocity:

$$\underline{v} = \dot{r}\,\underline{e}_r + r\dot{\theta}\,\underline{e}_\theta \quad -(86)$$

from which:

$$v^2 = \dot{r}^2 + r^2\dot{\theta}^2. \quad -(87)$$

From Section 2:

$$v^2 = \left(\frac{xL\epsilon}{\alpha m}\right)^2 \sin^2(x\theta) + \left(\frac{L}{mr}\right)^2 \quad -(88)$$

and using:

$$\sin^2(x\theta) = 1 - \frac{1}{\epsilon^2}\left(\frac{\alpha}{r} - 1\right)^2 \quad -(89)$$

it is found that:

$$v^2 = \left(\frac{L}{m\alpha}\right)^2 \left[\frac{2x^2\alpha}{r} - x^2(1-\epsilon^2) + \frac{\alpha^2}{r^2}(1-x^2)\right] \quad -(90)$$

When

$$x = 1 \quad -(91)$$

the Keplerian equation {11} for linear velocity is obtained:

$$v_N^2 = \left(\frac{L}{m\alpha}\right)^2 \left[\frac{2\alpha}{r} - (1-\epsilon^2)\right]. \quad -(92)$$

It is seen that the precession of the perihelion produces an additional term in $1/r^2$, and modifies the other two terms by a multiplicative factor x^2. This is again a simple classical description without the need for EGR. Eq. (90) can be tested experimentally.

The theory of deflection by gravitation can be developed very simply on the classical level by rewriting Eq. (8) as:

$$x\theta = \beta = \cos^{-1}\left(\frac{1}{\epsilon}\left(\frac{\alpha}{r} - 1\right)\right). \quad -(93)$$

The precession of the perihelion is given by:

$$x = \frac{1}{\theta}\cos^{-1}\left(\frac{1}{\epsilon}\left(\frac{\alpha}{r} - 1\right)\right) \quad -(94)$$

and the deflection by gravitation is given by the same equation:

$$\theta = \frac{1}{x}\cos^{-1}\left(\frac{1}{\epsilon}\left(\frac{\alpha}{r} - 1\right)\right). \quad -(95)$$

If for example r is initially R_0 and finally infinite then the change in deflection angle is:

$$\Delta\theta = \frac{1}{x}\left(\cos^{-1}\left(-\frac{1}{\epsilon}\right) - \cos^{-1}\left(\frac{\alpha}{R_0} - 1\right)\right) \quad -(96)$$

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4 Graphical description and discussion

The classical theory developed in this paper is depicted by some graphs which should make clear the meaning of the precession parameter x for the orbits. The conical section with precession is defined by

$$r = \frac{\alpha}{1 + \epsilon \cos(x\,\theta)} \tag{97}$$

as stated in Eq.(8) of section 2. For $x = 1$ the well known conical sections are obtained as shown in Fig. 1. All these types of curves are governed by the parameter ϵ. Choosing the additional parameter x different from unity leads to modifications of the conical sections and can result in drastic changes as will be seen later.

Starting with $\epsilon = 0$ we obtain a circle which is not affected by x. Giving ϵ a value between 0 and 1 leads to ellipses. Setting the factor $x \neq 1$ leads to a precession of the ellipse where the direction of precession depends on the choice of $x < 1$ or $x > 1$. Significant deviations from unity lead to change in the minor axis which becomes identical to the major axis, see Fig. 2. For $x = 2$ the curve is deformed and no more identifyable as an ellipse. Therefore we call this type of curves generated by Eq.(97) *generalized conical sections.*

The "generalization" effect of parabolas can be seen in Fig. 3. For values of x very different from unity the curves are more like spirals or hyperbolas than parabolas. For generalized hyperbolas (Fig. 4) the curves are distorted in a similar way. In all plots only the angular range of θ between 0 and 2π is shown in order not to overload the diagrams. A special case appears for hyperbolas with $x = 0.3$ as graphed in Fig. 5. Here the orbits are shown for a broader range of angles. Between $-\pi$ and π the orbit is a circle, showing that even closed orbits for $\epsilon > 1$ are possible for generalized conical sections. For larger angles some kinds of loops are observeable.

All this reminds to the alleged behaviour of "black holes" of the deprecated Einstein theory. If the central gravitational mass is very massive as reported

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for the centers of galaxies by astronomers, we can assume singificant deviations of x from unity, leading for example to the orbits of Fig. 5. Deflection of light can be described by the same Eq.(97). Therefore we can imagine the that light in the vicinity of such massive stars is bent completely around the center and is trapped. This would result in invisibility from outside, and the massive star would behave similar as a "black hole". All this is described on the basis of classical physics.

To develop this interpretation further, we know from the solar system that the innermost planet, Mercury, shows the highest precession of the elliptic orbit (although very small in size). This leads to the assumption that the value of the precession parameter x deviates the more from unity the nearer a planet moves around the center. For a highly ellptic orbit this means that x may depend on the orbital radius. We have performed model calculations assuming the dependence

$$x(r) = 1 \pm \frac{1}{(r+1)^6}. \tag{98}$$

This function is graphed in Fig. 6. It only deviates significantly from unity for $r < 1$. We have accounted for both possibilities $x > 1$ and $x < 1$ by both signs in (98). With this approach Eq.(97) takes the form

$$r = \frac{\alpha}{1 + \epsilon \cos(x(r) \cdot \theta)} \tag{99}$$

which is a transcendent equation, i.e. we cannot calculate the radius for a given angle θ directly. Instead we have implemented a numerical iterative scheme to obtain the dependence $r(\theta)$ numerically. The results for an ellipse are shown in Fig. 7. It is seen that the aphelion radius is not affected but there are significant deviations from the elliptic orbit for the perihelion. The precession in both directions comes out for both signs in $x(r)$ as expected, however there is an additional distortion of the ellipse in the near-perihelion range. This gives rise to the supposition that other deviations of planetary orbits than elliptical precession may be explainable by the behaviour of generalized conical sections. When the radius dependence of x is assumed to be more far reaching than in Eq.(99), calculations have shown that completely irregular orbits are possible. A lot of unexplored physics is hidden in the simple form of the equation for generalized conical sections.

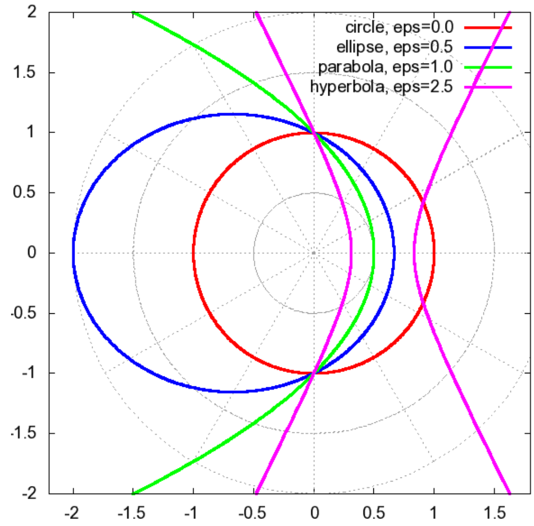

Figure 1: The different types of conical sections.

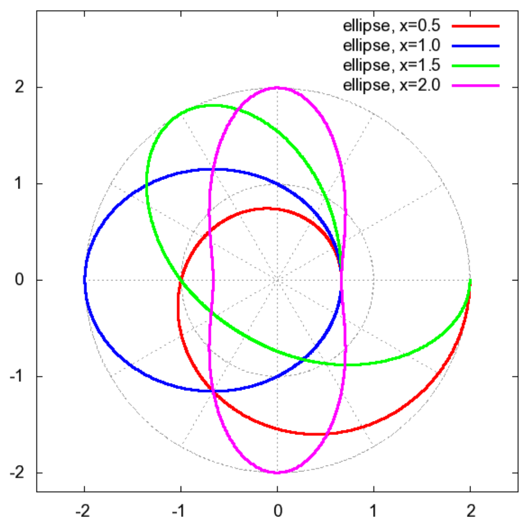

Figure 2: Generalized ellipses with $\epsilon = 0.5$.

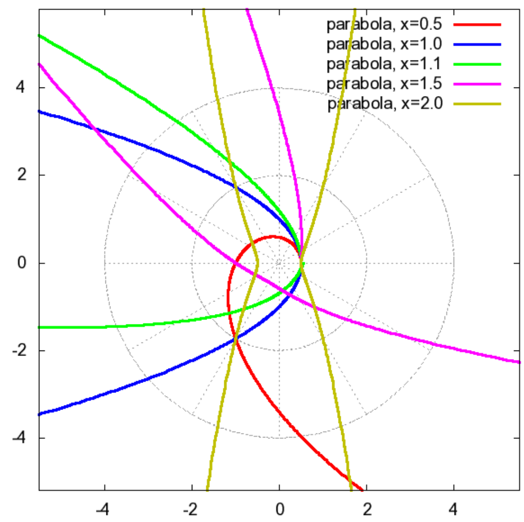

Figure 3: Generalized parabolas ($\epsilon = 1.0$).

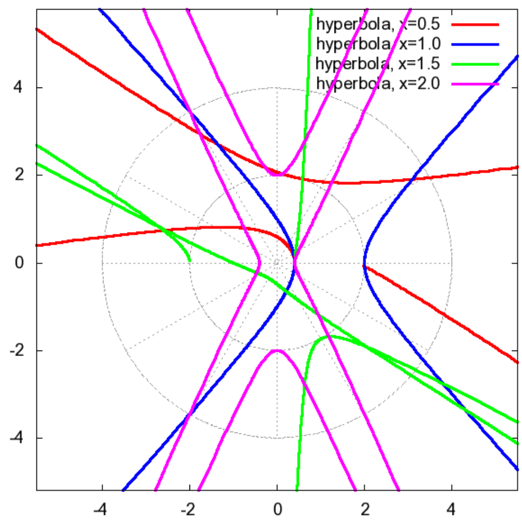

Figure 4: Generalized hyperbolas with $\epsilon = 1.5$.

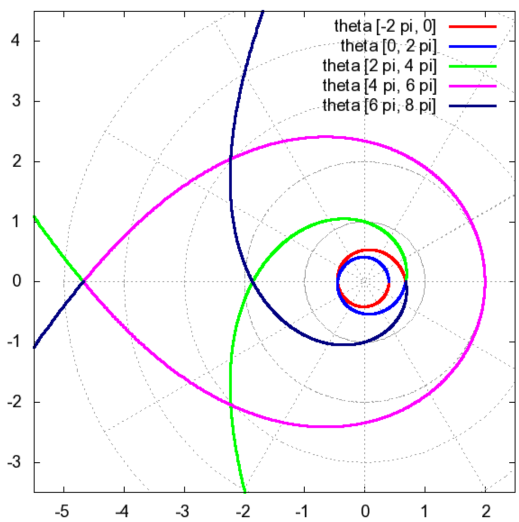

Figure 5: Special generalized hyperbola with $\epsilon = 1.5, x = 0.3$.

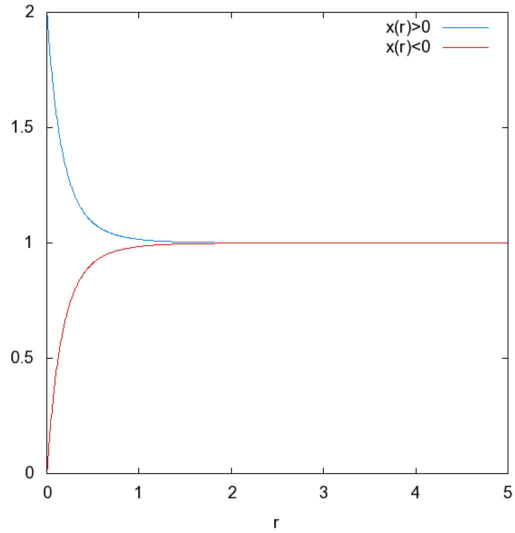

Figure 6: A model for an r dependent $x(r)$.

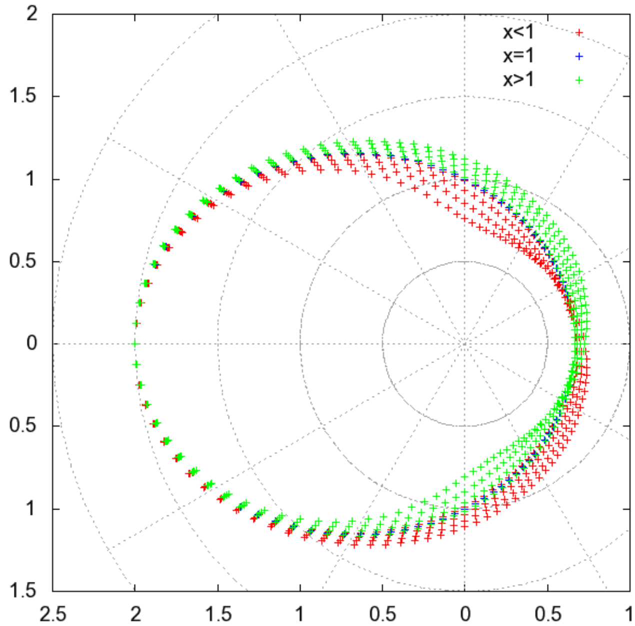

Figure 7: Elliptical orbits with variable function $x(r)$.

4 GRAPHICAL DESCRIPTION AND DISCUSSION

Section by Dr. Horst Eckardt

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